EFFECT OF BATCHING METHODS ON THE FRESH AND HARDENED PROPERTIES OF CONCRETE

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ABSTRACT

This paper investigated the effect of batching by mass and volume on concrete's compressive strength and workability. Influence of mix proportion at five levels and various water-cement ratios were also studied. All samples were cured by complete immersion in water and tested up to 28 days. The results indicated higher workabilities for concrete batched by mass than concrete batched by volume at all w/c ratios and mix proportions investigated. The workability increased with increase in w/c ratios in both methods. The compressive strength results showed that for rich structural mixes (1:1:2 and 1:1.5:3), concrete batched by mass had 20 % and 6 % strength increases respectively over the concrete batched by volume. Ordinary structural mix (1:2:4) had 14 % increase while non-structural mixes (1:3:6 and 1:4:8) had 8 % and 6 % increases respectively. In all cases, concrete batched by mass had better fresh and hardened properties of concrete.

Keywords: *Batching method, compressive strength, mix proportion; curing ages, water-cement ratio, workability*

1. INTRODUCTION

Several methods have been reported for specifying concrete mixes. The five principal ones are designated concretes, designed concretes, prescribed concretes, standardized prescribed concretes and proprietary concretes [1]. Concrete works are commonly carried out on most Nigerian construction sites for housing and similar construction where concrete is site-batched on a small site using standardized prescribed concretes which are batched by volume. Though Neville and Brooks [2] reiterated that volume batching is a bad practice, it is the usual practice on construction sites in Nigeria because it is easier, simpler and faster when compared to batching by mass. Most concrete specifications require that concrete be batched by mass and structural design is based on strength of concrete from such mix specifications and durability of concrete. Though volume batching is said to be generally restricted to non-structural works [3] where supervision could be poor, in the minor Nigerian construction environment, the practice is used for both structural and non-structural works which is in accordance with [1]. Traditionally, nominal mix which is now known as standardized prescribed concrete is batched in ratios (e.g. 1:1:2, 1:1½:3, 1:2:4 etc.) using head-pan or wheelbarrow measures. When batching by volume is used, possible sources of error could lead to variation in the amount of aggregate in a specific volume and errors in measured volume [3]. These errors often lead to variations in the fresh and hardened properties of concrete as against specified characteristics properties.

On the other hand, when a nominal mix is batched by mass using regularly maintained and well calibrated equipment, then high degree of uniformity in the fresh and hardened state properties of concrete can be achieved.

The design specification for a particular project may state nominal mix proportion and maximum coarse aggregate size to be used for structural and non-structural concrete (e.g. 1:2:4 or 1:3:6 - 19 mm Agg.), clarification is not usually made if the mix proportion is to be batched by mass or volume to achieve the specified characteristic strength. Also, the volume of water required for mixing is not often specified. The on-site practice is a visual assessment of the workability (consistence) of the concrete as water is added. Compressive strength obtained by this practice may be quite less than the specified characteristic strength and may differ from batch to batch of the concrete produced if the consistence is not measured.

Goldbeck and Gray [4] affirmed the need to establish the mix proportion with the materials to be used on site. This practice will enable appropriate mix proportion for a specified characteristic strength to be established after preliminary tests rather than the usual practice of recommending an unconfirmed mix ratio for a specified characteristic strength. With such practice, variations in the fresh and hardened state properties of concrete could ensue particularly from inaccuracies in measurement. Hence, the need to investigate the significance of variations in the properties of concrete produced by mass and volume.

2. EXPERIMENTAL PROGRAMME

2.1. Materials

Crushed granites stones with maximum size of 19 mm, sharp sand with a maximum size of 5 mm, Portland Cement type I (normal Portland cement) conforming to the requirement of BS EN 197-1 [5] and clean water from a nearby stream were used. All the materials were obtained from Ile-Ile, Osun State, Nigeria. The fineness modulus (FM) of the sharp sand used was 2.62.

2.2. Experimental Methods

Concrete was produced using batching by mass and volume from five mix proportions of 1:1:2, 1:1½:3, 1:2:4, 1:3:6, 1:4:8 and water-cement ratios ranging from 0.35 to 0.95. These mixes can be classified into three categories; rich structural mixes (1:1:2, 1:1½:3), ordinary structural mix (1:2:4) and non-structural mixes (1:3:6, 1:4:8). All specimens from both method of batching were hand-mixed until a uniform mix was achieved. Preparation and filling of moulds, hand compaction of concrete, surface levelling and curing were all done according the requirement of BS EN 12390-2 [6]. The fresh concretes from the different mixes were tested for slump according to the requirement of BS EN 12350-2 [7]. Three replicates of concrete cube specimens were made for each variable. The average values of the maximum loads at which each group of three specimens failed was found and the compressive strength determined accordance to the requirement of BS EN 12390-3 [8].

2.3. Method of Proportioning

Batching by volume and mass were adopted in measuring the constituent materials such as cement, sand, granite stone and water. Batching by mass was achieved by using a weighing balance. This was done for all mix proportions. Water for mixing was also weighed out as a function of the weight of cement used for each mix proportion. Batching by volume was achieved by using a constructed gauge box for proportioning the materials according to the various mix proportions and based on the quantity of material needed per batch.

3. RESULTS AND DISCUSSION

3.1. Effect of batching methods on slump of concrete

The comparison of the slump of concrete batched by mass and volume for 1:1:2, 1:1½:3, 1:2:4, 1:3:6, 1:4:8 at water-cement ratios of 0.35 to 0.95 are presented in Table 1.

The results clearly indicated that the slump of concrete batched by mass is higher than those batched by volume for all mix proportions and at all the water-cement ratios. The reason for this observation can be attributed to the fact that materials batched by mass were exact in measurement taking cognisance of the differences in the material properties while variations in quantity are most likely for materials batched by volume.

It is worth noting that from the results shown in Table 1, for all the mix proportions and at the individual water-cement ratios, the percentage differences in slump between the concrete batched by mass and volume lies between 4-30 % with most in the range of 4-10 %. Hence, batching by mass and by volume using same mix proportion will obviously result in different concrete properties which will impact on the compressive strength.

Table 1. Variation in slump between concrete batched by mass and volume

Mix Proportion	w/c ratio	Slump (mm)		Slump difference (mm)	Slump class	
		By mass	By volume		By mass	By volume
1:1:2	0.35	2.0	0.0	2.0	-	-
	0.40	32.0	26.0	6.0	S1	S1
	0.45	83.0	76.0	7.0	S2	S2
	0.50	168.0	146.0	22.0	S4	S3
1:1½:3	0.45	1.0	0.0	1.0	-	-
	0.50	35.0	24.0	11.0	S1	S1
	0.55	86.0	81.0	5.0	S2	S2
	0.60	174.0	162.0	12.0	S4	S4
1:2:4	0.55	5.0	2.0	3.0	-	-
	0.60	44.0	36.0	8.0	S2	S1
	0.65	84.0	63.0	21.0	S2	S2
	0.70	174.0	166.5	7.5	S4	S4
1:3:6	0.65	0.5	0.0	0.5	-	-
	0.70	44.0	38.0	6.0	S2	S1
	0.75	68.0	56.0	12.0	S2	S2
	0.80	165.0	152.0	13.0	S4	S4
1:4:8	0.75	2.0	0.5	1.5	-	-
	0.80	36.0	32.5	3.5	S1	S1
	0.85	72.0	66.0	6.0	S2	S2
	0.95	145.0	132.0	13.0	S3	S3

* S1 (≥ 10 ≤ 40), S2 ((≥ 50 ≤ 90), S3 (≥ 100 ≤ 150), S4 (≥ 160 ≤ 210) according to BS EN 206-1:2000

3.2. Effect of w/c ratio on the slump when batched by mass and by volume

The effect of w/c ratio on the workability of concrete batched by mass and volume are also shown in Table 1. In both method of batching, the slump of concrete increased with increase in w/c ratio with concrete batched by mass giving higher slump at all w/c ratios. The variation in the slump of both methods of batching is an indication of the non-uniformity of the mixes. At w/c ratios of 0.35, 0.45, 0.55, 0.65 and 0.75 for all mix proportions, slump were between 0 and 2 mm indicating mixes of stiff consistency. For concrete batched by mass, slump of mix ratio 1:1:2 at w/c ratios between 0.40 and 0.50 varies from medium to very high slump while for the counterpart batched by volume, it varies from low to high [9]. A comparison of both batching methods for other mix proportions and at the w/c ratios tested for as indicated in Table 1, a similar pattern can be observed. The differences in slump between both methods were not significant at lower w/c ratios for all the mix proportions. The differences were pronounced with increase in w/c ratios for all mixes.

3.3. Compressive strength result

The result of the compressive strengths of concrete specimens at five levels of mix proportions and different water-cement ratios for batching by mass as compared to those batched by volume are presented in Figures 1-16.

Figures 1 and 2 show that the compressive strengths increased progressively from 7 to 28 days with increase in curing ages for both methods of batching. Also, the Figures show that the higher the w/c ratios, the lower the compressive strength. This is the general pattern for all mixes investigated as well documented in literature. However, a comparison of the effect of batching methods on the compressive strength of concrete with mix proportion of 1:1:2, which is a rich structural mix, revealed that the compressive strength of concrete batched by mass is higher than that batched by volume at all w/c ratio and for curing ages 7 to 28 days. For example, on the 28th day, at w/c = 0.50, which corresponds with a high slump concrete, the compressive strength of concrete batched by mass is higher by 20 % compared to that batched by volume. This shows a significant difference in strength attained on the 28th day from the two methods of batching. Hence, there is a high likelihood that most concrete produced in the Nigerian construction sites do not meet the designed target strength. This may not the unconnected with the high increase of building collapse the country has been witnessing in recent times.

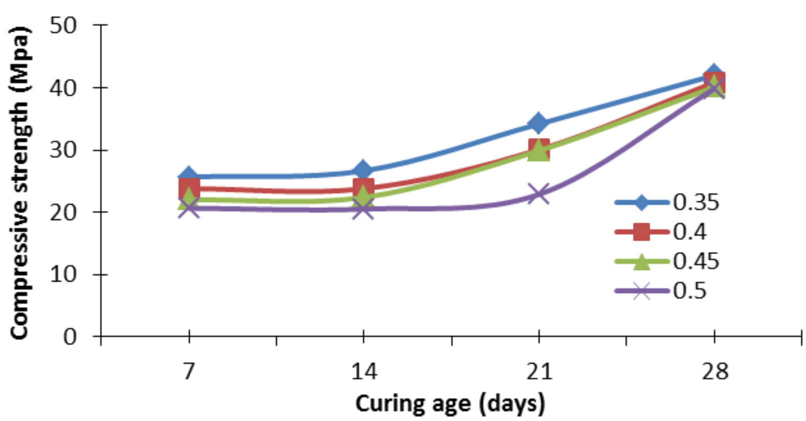

Figure 1. Variation of compressive strength with curing age at different w/c ratios when batched by mass (1:1:2)

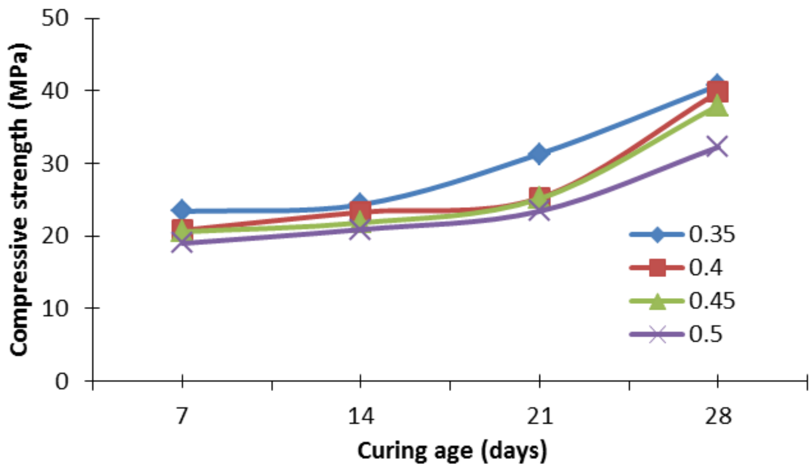

Figure 2. Variation of compressive strength with curing age at different w/c ratios when batched by volume (1:1:2)

With mix ratio 1:1½:3, the difference in the 28th day compressive strength is about 6 % with concrete batched by mass having an advantage over concrete batched by volume at w/c = 0.60 which represents a high slump (Figs. 3 & 4). It should however be noted that the method of batching here for both method is even more accurate than what obtains on a typical Nigerian construction site where water is added arbitrarily. Hence higher variation is expected.

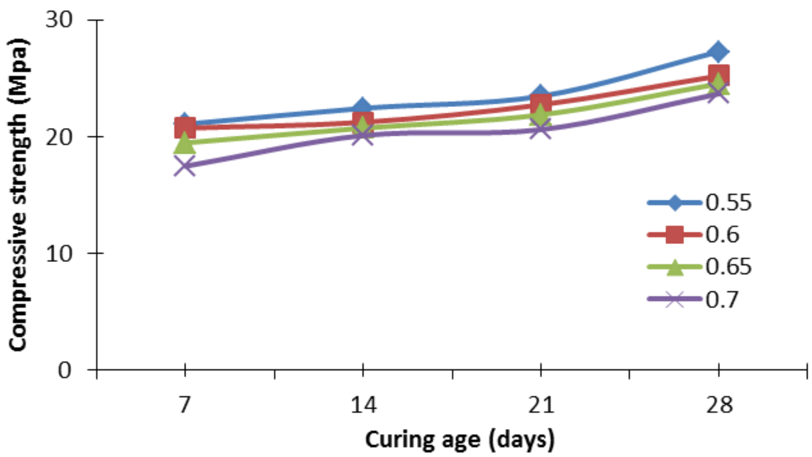

Figure 3. Variation of compressive strength with curing age at different w/c ratios when batched by mass (1:1½:3)

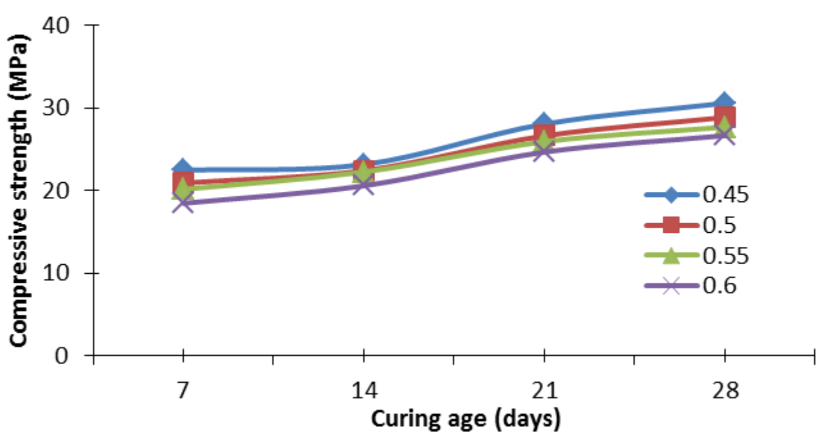

Figure 4. Variation of compressive strength with curing age

at different w/c ratios when batched by volume (1:1½:3)

For the ordinary structural mix (1:2:4) which is commonly used for structural work, concrete batched by volume was about 13 % less in 28th day compressive strength to concrete batched by mass at w/c = 0.70 (very high slump) and about 14 % less with w/c = 0.65 (medium slump). 28th day compressive strength of concrete obtained by volume proportion was 18.77 MPa while that obtained by mass proportioning was 21.87 MPa. It is evident that concrete batched by volume did not meet the requirement of 20 MPa for structural concrete for 1:2:4 concrete mix (Figures 5 & 6).

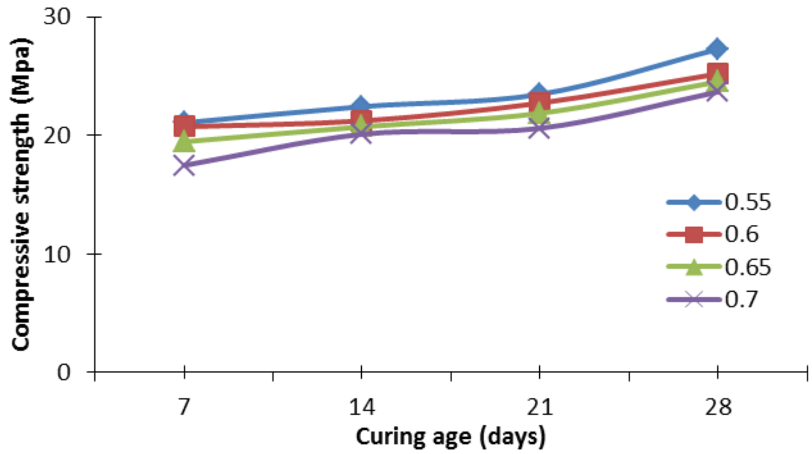

Figure 5. Variation of compressive strength with curing age at different w/c ratios when batched by mass (1:2:4)

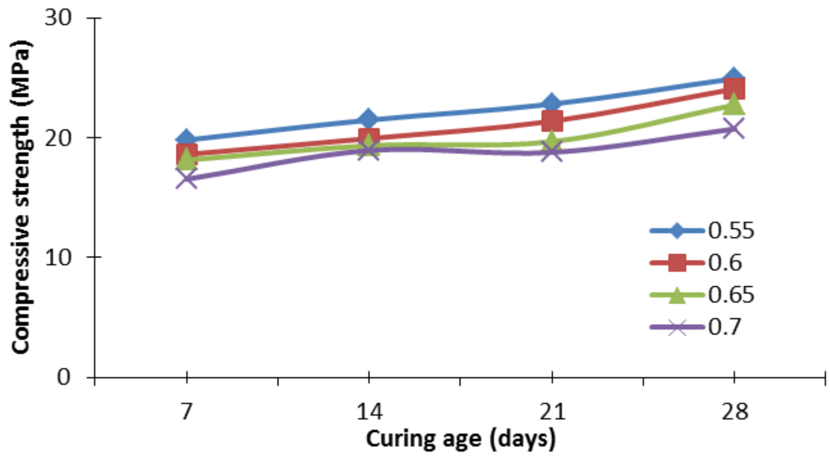

Figure 6. Variation of compressive strength with curing age at different w/c ratios when batched by volume (1:2:4)

Figures 7 to 10 present the compressive strength relationship between concrete by mass and volume for concrete usually used as mass concrete (1:3:6 and 1:4:8). For 1:3:6 mixes, concrete batched by mass had higher compressive strength on the 28th day differing by about 8 % and 11 % at w/c = 0.75 and 0.80 (medium and high slumps) respectively from concrete batched by volume while for 1:4:8 mixes, it differs by about 6 % when w/c = 0.95 and 10 % when w/c = 0.85.

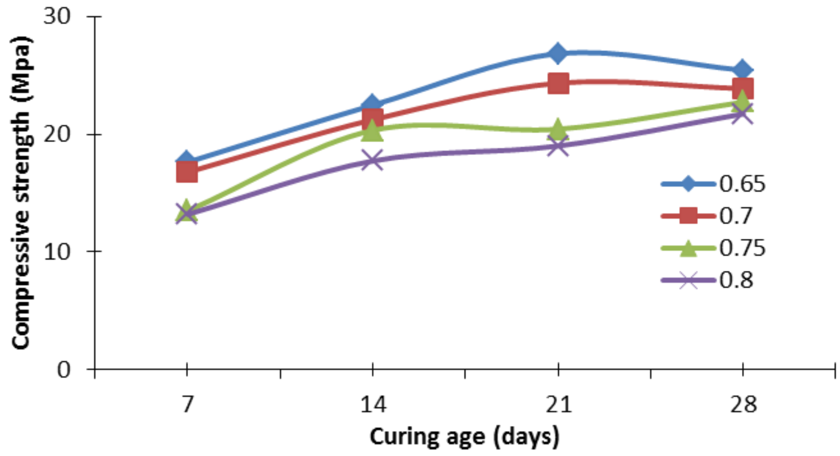

Figure 7. Variation of compressive strength with curing age at different w/c ratios when batched by mass (1:3:6)

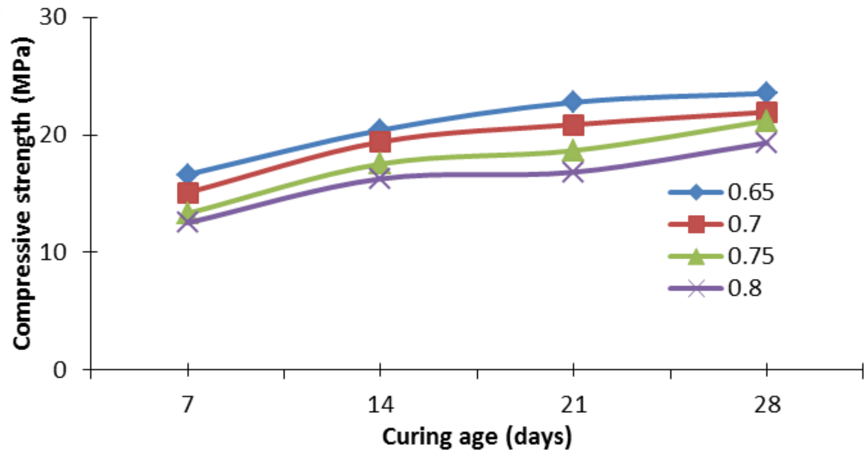

Figure 8. Variation of compressive strength with curing age at different w/c ratios when batched by volume (1:3:6)

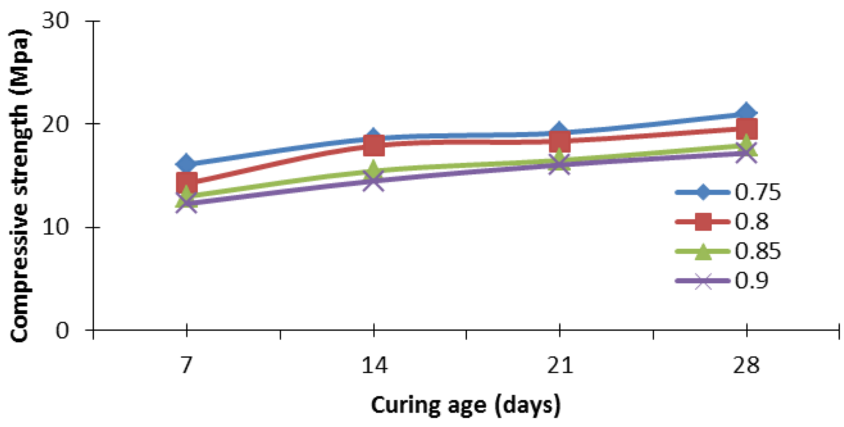

Figure 9. Variation of compressive strength with curing age at different w/c ratios when batched by mass (1:4:8)

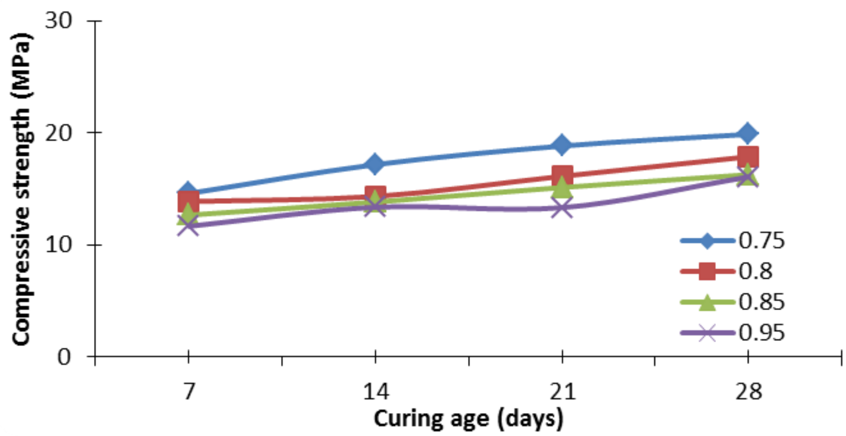

Figure 10. Variation of compressive strength with curing age at different w/c ratios when batched by volume (1:4:8)

4. CONCLUSIONS

The effect of two methods of batching (mass and volume) on the consistence (workability) and compressive strength properties of concrete has been investigated. This study has revealed that for a given mix proportion, batching by mass will give variations in fresh and hardened properties of concrete when same mix proportion is batched by volume which is commonly used in most construction sites in Nigeria. Slump variation between both methods was up to 30 % while compressive strength was up to 14 % with concrete batched by mass having higher workabilities as well as compressive strength particularly for 1:2:4 mix which is commonly used for ordinary structural concrete in Nigeria. This gives an indication that compressive strength obtained from batching by volume in a typical construction site in Nigeria will most likely be less than the designed target strength. Though it may not be practicable to batch by mass on minor site, it is recommended that a preliminary test be done to ascertain the exact volume proportion that will give the design target strength rather than specifying an unconfirmed standard mix proportion.

5. REFERENCES

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